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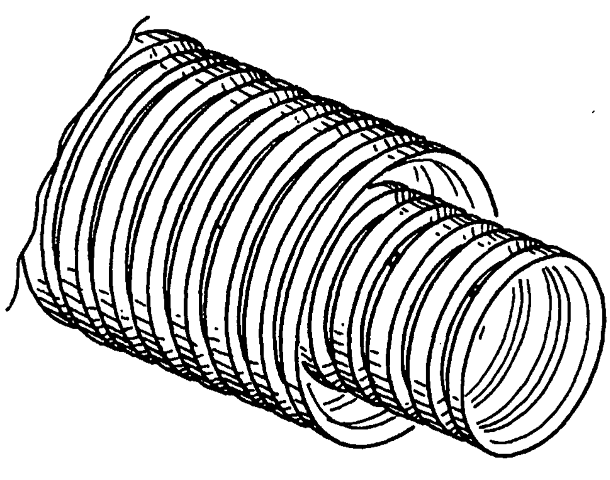
(54) Title: AN AIR DISTRIBUTOR FOR A BIOLEACHING SYSTEM



(57) Abstract: An air distributor for use in heap or dump leaching systems is disclosed. The air distributor includes an air pipe having a series of holes for releasing air from the pipe and one or more protective members spaced outwardly of the air holes to shield the air holes.

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AN AIR DISTRIBUTOR FOR A BIOLEACHING SYSTEM

The present invention relates to bioleaching.

The present invention relates particularly to an air distributor for supplying air to a heap or dump of material being bioleached.

The term "heap" as used herein is understood to describe material that has been crushed and agglomerated and stacked mechanically in a pile.

The term "air" as used herein is understood to mean atmospheric air with or without modification of the gas composition.

The term "dump" as used herein is understood to describe material, such as run-of-mine material, that has been directly discharged from a truck into a pile.

The present invention is described in the context of bioleaching copper-bearing sulphide minerals to recover copper. However, the present invention is not limited to bioleaching this material and to recovering this metal and extends to bioleaching any material in a heap/dump that requires air to be delivered to the heap/dump.

Historically, copper was produced in the 16th century at both the Harz mountains in Germany and Rio Tinto in Spain using bacteria-assisted leaching. The role played by the bacteria was not known to the metallurgists of the time. During the 1960's Kennecott Copper Company led a research and operational program to understand the

role of aeration, solution chemistry, dump design etc. and this understanding expanded the application of heap and dump leaching. Also, the need to stop acid mine drainage and the development of biooxidation technology for refractory gold contained in sulphides has expanded the understanding of the role of microorganisms and this knowledge is available to the copper industry. Even with all these advancements bioleaching technology is still in its infancy and, to optimize it, there is a need to understand fully the interaction of the biological, chemical, fluid, mass and heat transfer phenomena.

Bioleaching is growing in importance for the production of copper because of the need for environmentally friendly technology that is simple to implement and offers both considerable capital and/or operating cost savings. However, the application of bioleaching has not been easy and a lack of understanding of the key issues has caused industrial projects to fail to meet the designed production and/or delays in reaching the design capacity.

Ferric ions are an effective oxidizing agent at ambient conditions for the oxidation of copper-bearing sulphides in order to release copper into a soluble and thereafter recoverable form.

Oxidation of ferrous ions to ferric ions involves the following reaction:

$$\boxed{4Fe^{+2}\ (aq) + O_2\ (g) + 4H^+ \xrightarrow{\text{bacteria}} 4Fe^{+3}\ (aq) + 2H_2O}$$

It can be seen from the above equation that oxidation of ferrous ions to ferric ions is not possible in the absence of acid and oxygen.

Bacteria such as Thiobacillus ferrooxidans, Leptospirillum ferrooxidans, and Thiobacillus thiooxidans catalyse oxidation of ferrous ions to ferric ions at a rate 10^6 times faster than via gaseous oxygen alone.

The bacteria are unicellular microorganisms requiring oxygen, carbon dioxide for the synthesis of organic compounds, traces of nutrients (ammonium, magnesium, calcium, potassium, sulphate, and phosphate ions) for their metabolic functions, an acidic environment, and a suitable temperature. The lack or absence of the above parameters decreases the bacterial activity and causes a decrease in the oxidation rate of copper sulphides resulting in less copper dissolution.

Biological leaching of sulphides requires air.

Initially heap/dump plants relied on natural advection but this was found to be inadequate.

In recent years plants have moved to air injection. As the heaps/dumps are usually very big this has to be done cheaply and the general solution has been to blow low pressure (typically 1-3 psi) air through corrugated HDPE pipes which are buried in the ore or in inert overliner material under the ore. In a typical industrial application the pipes are usually long, upwards of 500m in big plants, and have air holes every 1-4 m along the length of the pipes in order to distribute air

in the heaps/dumps. The air holes are usually small (1-4mm) and the experience of the applicant is that the holes tend to become blocked very quickly. Blocking of air holes is caused by fine solids and precipitates/crystals which are carried to the air pipes by the leach solutions percolating through the heap/dump.

An object of the present invention is to provide an air distributor that is considerably less susceptible to blocking than the corrugated HDPE pipes with small air holes described in the preceding paragraph.

According to the present invention there is provided an air distributor which includes an air pipe having a series of holes for releasing air from the pipe and one or more protective members spaced outwardly of the air holes to shield the air holes.

In use, when the air distributor is embedded in a heap or dump of material being bioleached and leaching solution is percolating through the heap/dump, the protective member or members prevent solution contacting the air holes and depositing material (carried by the solution) that could block the air holes.

The air pipe may be any suitable shape.

For example, the air pipe may be cylindrical.

The air pipe may also be corrugated, with a series of circumferential crests and troughs along the length of the pipe.

Preferably the air holes are in the troughs of the corrugations.

In a situation in which the air distributor includes a single protective member as opposed to a plurality of members, the member may be in the form of an outer pipe that is spaced outwardly of the air pipe whereby there is a gap between the air pipe and the outer pipe.

With this arrangement, preferably the outer pipe does not restrict air flow from the air holes in the air pipe.

The outer pipe may have a series of air holes for air that flows in use from the air pipe into the gap between the air pipe and the outer pipe via the air holes in the air pipe.

Preferably, the air holes in the outer pipe are larger than the air holes in the air pipe and therefore are less susceptible to being blocked.

In an alternative embodiment, that applies to situations in which the air pipe is corrugated, the single protective member may be in the form of a sheet member that is at least partially wrapped around the air pipe and contacts the crests of the corrugations and extends over and covers the troughs that include air holes.

In another alternative embodiment, that also applies to situations in which the air pipe is corrugated, the single protective member may be in the form of a

corrugated member that is at least partially wrapped around the air pipe, with the crests and troughs of the corrugated member overlying and spaced outwardly of the crests and troughs respectively of the air pipe.

With the above alternative embodiments, preferably the single protective members do not restrict air flow from the air holes in the air pipe.

In a situation in which the air distributor includes a plurality of protective members as opposed to a single member, each member may be in the form of a section of an outer pipe that is spaced outwardly of the air pipe, whereby there are gaps between the outer pipe sections and the outer pipe.

Preferably the outer pipe sections do not restrict air flow from the air holes in the air pipe.

The outer pipe sections may have a series of air holes for air that in use flows from the air pipe into the gaps between the air pipe and the outer pipe sections via the air holes in the air pipe.

Preferably, the air holes in the outer pipe sections are larger than the air holes in the air pipe and therefore are less susceptible to being blocked.

In alternative embodiments, each protective member of the plurality of protective members may be in the form of a section of the above-described sheet member or a section of the above-described corrugated member.

The outer pipe may be a solid pipe with open ends, whereby air flow from the air pipe sections can be released from the air distributor via the ends of the outer pipe sections.

The air pipe and the protective member or members may be made from any suitable material.

The air holes in the air pipe may be any suitable shape. Specifically, the present invention is not limited to arrangements in which the air holes are circular.

The air holes in the air pipe may be any suitable size or spacing.

The air holes in the outer pipe or outer pipe sections may be any suitable shape. Specifically, the present invention is not limited to arrangements in which the air holes are circular. Typically, the air holes are slots that are relatively long compared to the width of the slots.

The air holes in the outer pipe or outer pipe sections may be any suitable size or spacing.

According to the present invention there is also provided a heap or dump leaching system for heap or dump leaching a material that includes the above-described air distributor positioned in and supplying air to a heap or dump of the material.

The present invention was made during the course of an extensive laboratory/pilot plant program carried out

by the applicant to investigate key operating parameters of bioleaching copper-bearing ore.

As expected, the laboratory work of the program established that the absence of aeration significantly decreased the copper leaching kinetics of the ore. Tests with no air reached 50% total copper recovery whereas tests with air reached a copper recovery in the +80% range.

The pilot plant work of the program was carried out at a bioleaching pilot plant that included crushing, agglomeration, leaching (in cribs and columns), solvent-extraction, and electro winning stages. The major focus of the pilot plant work was on the leaching process and the plant was designed to simulate industrial heap leaching plants.

The plant included 12 concrete cribs (two cribs of 4 m x 5 m x 6 m high and ten cribs of 2 m x 2.5 m x 6 m high). Each crib had internal and external insulation in order to simulate conditions in a rectangular section of an industrial heap. The amount of insulation was calculated to be equivalent to that provided by 5 m of ore around the crib.

In addition, the plant included a total of 27 columns, 24 having 0.30 m ID and 3 columns having 0.60 m ID. The 0.30 m ID columns were 6 m high and the 0.60 m columns were 12 m high. All of the columns were insulated on the same basis as the cribs.

The plant included a solution collection and irrigation system. The system was similar to that used in industrial heap leaching plants.

The plant included an aeration system. Air was added to the sulphide heaps by blowing low-pressure (1-3 psi) air via the aeration system. The aeration system included a plurality of air distribution pipes. The air distribution pipes were in the form of corrugated HDPE air pipes having circumferential crests and troughs along the length of the pipes and holes in the troughs of the corrugations. The air pipes were placed at the base of the heaps, usually above the phreatic level of the heaps.

A stacker was employed to load the cribs with ore in a similar procedure to that used in industrial heap leaching plants.

A major problem experienced in initial crib testwork at the pilot plant was plugging of the air holes in the air pipes inhibiting bacterial activity in the ore and therefore limiting copper recovery.

In the initial pilot plant work the start-up air flowrate was maintained for just 15 days and then started to decrease. At day 57 all of the air holes were completely blocked.

XRD analysis performed on the material responsible for plugging the air holes showed that the material was fine solids and precipitates carried to the air pipes by the irrigation solution.

In response to the air hole blocking problem, the applicant designed and tested in the pilot plant several preferred embodiments of an air distributor of the present invention, one of which is shown in Figure 1.

The embodiment of the air distributor shown in Figure 1 is in the form of the above-described corrugated HDPE air pipe located inside another pipe of larger diameter. The outer pipe forms a protective member that shields the air holes in the air pipe. The outer pipe is similar to the air pipe but with a plurality of holes (the actual pipe used was the pipe normally used for collecting solutions, sometimes called a "drainflex" pipe). The holes in the outer pipe were much larger than those used in the air pipe and were sufficiently large so that the holes did not become blocked.

The other embodiment of the air distributor tested by the applicant included short sections of the outer pipe shown in Figure 1 - without air holes - positioned to enclose the sections of the air pipe that have holes. The use of air pipe sections greatly reduced the total length of the outer pipe required. It was not necessary to provide holes in the outer pipe sections because air could flow from the ends of the outer pipes.

Table 1 summarises the testwork carried out by the applicant on the preferred embodiment shown in Figure 1 and comparative testwork on the air pipe only - without the outer pipe.

The testwork was carried out in pilot plant cribs. Distributors 1 to 3 were installed 1 m from the

base of the cribs and distributors 4 to 6 were installed 1,5 m from the base of the cribs.

TABLE 1: DETAILS OF AIR DISTRIBUTOR TESTS

TEST	# OF ORIFICES	ID (MM)	TYPE OF AIR DISTRIBUTOR	PROTECTION	LOCATION OF ORIFICES
1	10	2	Corrugated line	No	5 in the valley & 5 in the top
2	10	2	Corrugated line	Inside a 4" Drenflex line	5 in the valley & 5 in the top
3	3	4	Corrugated line	No	2 in the valley & 1 in the top
4	3	4	Corrugated line	Inside a 4" Drenflex line	2 in the valley & 1 in the top
5	3	4	PVC line	Inside a 4" Drenaflex line	line
6	1	6	Corrugated line	No	Top

The main variables investigated were the size of the air holes, the number of air holes, the location of the air holes on the corrugated air pipes (valley vs. top), the air distributor material, and protection.

The results of the evaluation of the air distributors show that only tests 2, 4, and 5 were able to maintain the set air flowrate of about 60 L/min. These air distributors are the distributors protected with the "drainflex" pipe.

The air distributors of the other tests plugged after only 45 operating days.

In general, the applicant believes that a key aspect of the protection system provided by the preferred embodiment of the air distributor shown in Figure 1 is that the outer pipe prevents contact of the leach solution with the air holes. Specifically, the applicant suspects that solution percolating down through the heap contacts the outer pipe and follows the curvature of the outer pipe and is thus kept away from the air pipe. No solution at the air holes in the air pipe means no plugging. In addition, the outer pipe performed this task successfully without impeding air flow from the air pipe. Specifically, there was a gap of about 1 cm between the air pipe and the outer pipe and the gap was sufficient to allow uninterrupted air flow. In an industrial application this gap could be larger depending on the relative sizes of the pipes used.

The applicant carried out pilot plant work to assess the performance of the above-described preferred embodiments of the air distributor against other protection systems, namely sock and mesh cloth systems.

A crib was loaded with 100% -1/2" MHE-A-CC mineral that was agglomerated with 4,2 kg/MT of acid and 49,5 kg/MT of water. A stacker was used to load the agglomerated ore in the crib and 8 air distributors were installed at the bottom of the crib. Distributors 1 to 4 were installed 1 m from the base of the crib and distributors 5 to 8 were installed 1,5 m from the base.

Table 2 summarizes the types of air distributors used.

TABLE 2: SUMMARY OF AIR DISTRIBUTORS

TEST	# OF ORIFICES	DIAMETER OF ORIFICES (mm)	TYPE OF AIR LINE	LOCATION OF ORIFICES IN AIR DISTRIBUTOR	PROTECTION
D1	3	4	Corrugated line	all on top	Drenaflex
D2	3	4	Corrugated line	all on top	Sock
D3	3	4	Corrugated line	all on top	Drenaflex cuts (about 30cm)
D4	3	4	Corrugated line	all on top	Mesh cloth over orifices
D5	3	4	Corrugated line	all at the side (top)	Sock
D6	3	4	Corrugated line	all on top	No protection
D7	3	4	Corrugated line	all on top	Sock with humidified
D8	3	4	Corrugated line	all in valley	Sock

Figure 2 shows a graph that displays the air flowrate as a function of leaching time for the 8 air distributors.

It is evident from the figure that almost immediately on start-up there was a decrease in the air flowrate of air distributors D2, D5, and D7. These

distributors had two things in common, namely: the use of a sock and all the air holes were in the top of the air pipes. Within a 7-8 day period, the air flowrate in these air distributors was approximately 58% of the desired flow rate.

After only 16 days of operation air distributors D7 and D6 became plugged completely.

Distributor D6 had no protection and therefore was expected to plug in the first 30 days based on previous crib testwork.

By the end of 3 months of operation it was evident that only the air distributors D1 and D3, ie the preferred embodiments of the air distributors, were able to maintain the air flowrate and it was decided to end the evaluation.

The evaluation of the air distributors demonstrated that only distributors D1 and D3 were able to maintain the set air flowrate of 56,5 L/min.

A key finding was that an air distributor protected only with short sections of outer pipe located at sections of the air pipe having air holes performed as well as full-length protection. This is important because it translates to savings at the industrial stage.

The applicant has developed and has tested successfully two other embodiments of an air distributor of the present invention. These embodiments are shown in Figure 3 to 6.

Figure 3 illustrates both embodiments of the air distributor. Figure 4 is a detailed view of one of the embodiments and Figure 5 is a detailed view of the other of the embodiments. Figure 6 is an end view of the air distributor shown in Figure 3.

Figure 3 is a side elevation that illustrates a corrugated HPDE air pipe 33 that has air holes 35 in the troughs of the corrugations. Figure 3 also illustrates a sheet member 37 and a corrugated member 39 welded to the crests of the corrugations of the air pipe 33. The sheet member 37 and the corrugated member 39 form protective members that shield the air holes 35 in the air pipe 33. The combination of the air pipe 33 and the sheet member 37 form one embodiment and the combination of the air pipe 33 and the corrugated member 39 form the other embodiment.

The sheet member 37 is a flat sheet that is wrapped approximately 270° around the circumference of the air pipe 33. The sheet member 37 extends across and covers the troughs that have the air holes 35 and thereby forms a series of channels that are defined by the sheet member 37 and the troughs. In use, the air distributor is positioned in a heap with the sheet member 37 extending over the upper section of the air distributor so that the sheet member 37 shields the air holes 35 from downwardly flowing solution. Air can flow from the air pipe 33 via the air holes 35 along the channels that are defined by the sheet member 37 and the troughs to the ends of the sheet member 37 and then into the heap.

The corrugated member 39 is identical to the sheet member 37 in terms of location on the air pipe 33

and function. The corrugated member 39 is arranged so that the crests overlie the crests of the air pipe 33 and the troughs overlie the troughs of the air pipe 33, whereby there are gaps between the crests and gaps between the troughs.

As indicated above, both embodiments shown in Figures 3 to 6 have been tested successfully by the applicant.

Many modifications may be made to the preferred embodiment of the present invention described above without departing from the spirit and scope of the invention.

CLAIMS:

1. An air distributor which includes an air pipe having a series of holes for releasing air from the pipe and one or more protective members spaced outwardly of the air holes to shield the air holes.

2. The distributor defined in claim 1 wherein the air pipe is cylindrical.

3. The distributor defined in claim 1 wherein the air pipe is corrugated, with a series of circumferential crests and troughs along the length of the pipe.

4. The distributor defined in claim 3 wherein the air holes are in the troughs of the corrugations.

5. The distributor defined in any one of the preceding claims includes a single protective member as opposed to a plurality of members and the protective member is in the form of an outer pipe that is spaced outwardly of the air pipe, whereby there is a gap between the air pipe and the outer pipe.

6. The distributor defined in claim 5 wherein the outer pipe does not restrict air flow from the air holes in the air pipe.

7. The distributor defined in claim 5 or claim 6 wherein the outer pipe has a series of air holes for air that passes from the air pipe into the gap between the air pipe and the outer pipe via the air holes in the air pipe.

8. The distributor defined in claim 7 wherein the air holes in the outer pipe are larger than the air holes in the air pipe and therefore are less susceptible to being blocked.

9. The distributor defined in any one of claims 1 to 4 includes a single protective member as opposed to a plurality of members and the air pipe is corrugated and the single protective member is in the form of a sheet member that is at least partially wrapped around the air pipe and contacts the crests of the corrugations and extends over and covers the troughs that include air holes.

10. The distributor defined in any one of claims 1 to 4 includes a single protective member as opposed to a plurality of members and the air pipe is corrugated and the single protective member is in the form of a corrugated member that is at least partially wrapped around the air pipe, with the crests and troughs of the corrugated member overlying and spaced outwardly of the crests and troughs respectively of the air pipe.

11. The distributor defined in claim 9 or claim 10 wherein the single protective member does not restrict air flow from the air holes in the air pipe.

12. The distributor defined in any one of claims 1 to 4 includes a plurality of protective members as opposed to a single member and each protective member is in the form of a section of an outer pipe that is spaced outwardly of the air pipe, whereby there are gaps between the outer pipe sections and the outer pipe.

13. The distributor defined in claim 12 wherein the outer pipe sections do not restrict air flow from the air holes in the air pipe.

14. The distributor defined in claim 12 or claim 13 wherein the outer pipe sections have a series of air holes for air that passes from the air pipe into the gaps between the air pipe and the outer pipe sections via the air holes in the air pipe.

15. The distributor defined in claim 14 wherein the air holes in the outer pipe sections are larger than the air holes in the air pipe and therefore are less susceptible to being blocked.

16. The distributor defined in any one of claims 1 to 4 includes a plurality of protective members as opposed to a single member and each protective member is in the form of a section of a sheet member that is at least partially wrapped around the air pipe and contacts the crests of the corrugations and extends over and covers the troughs that include air holes.

17. The distributor defined in any one of claims 1 to 4 includes a plurality of protective members as opposed to a single member and each protective member is in the form of a section of a corrugated member that is at least partially wrapped around the air pipe, with the crests and troughs of the corrugated member overlying and spaced outwardly of the crests and troughs respectively of the air pipe.

18. The distributor defined in any one of the preceding claims wherein the outer pipe is a solid pipe with open ends, whereby air flow from the air pipe sections can be released from the air distributor via the ends of the outer pipe sections.

19. A heap or dump leaching system for heap or dump leaching a material that includes the air distributor defined in any one of the preceding claims positioned in and supplying air to a heap or dump of the material.

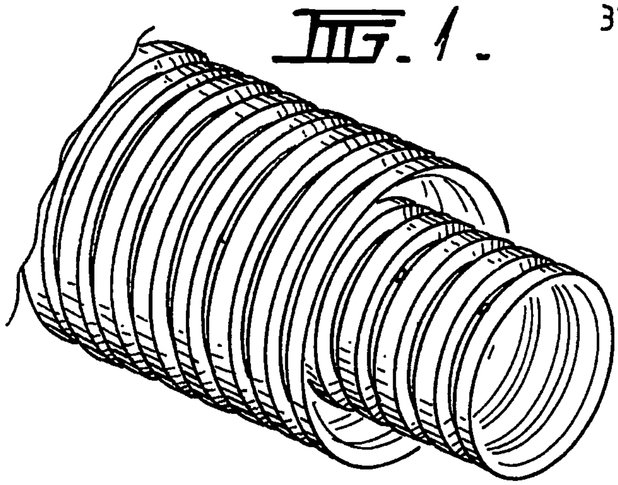


FIG. 1.

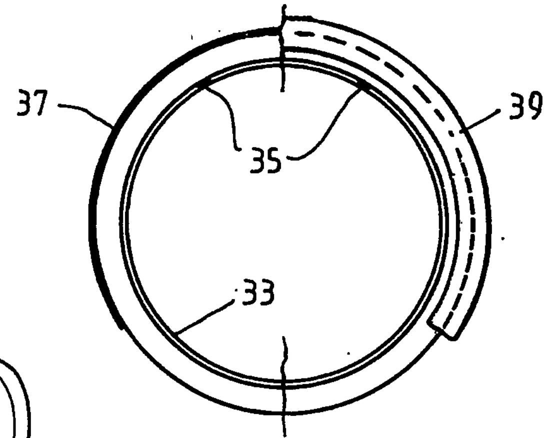


FIG. 6.

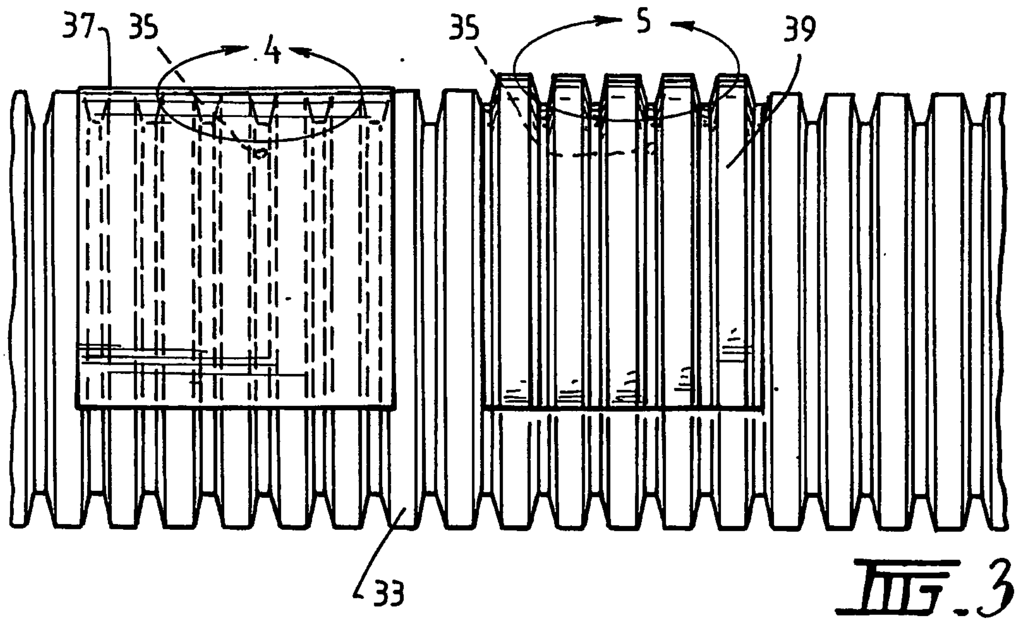


FIG. 3.

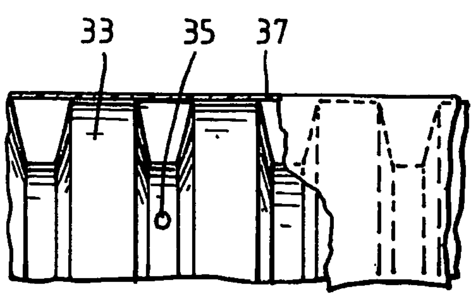


FIG. 4.

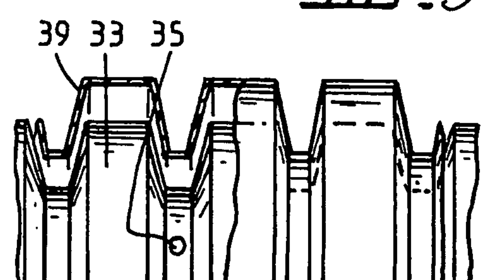
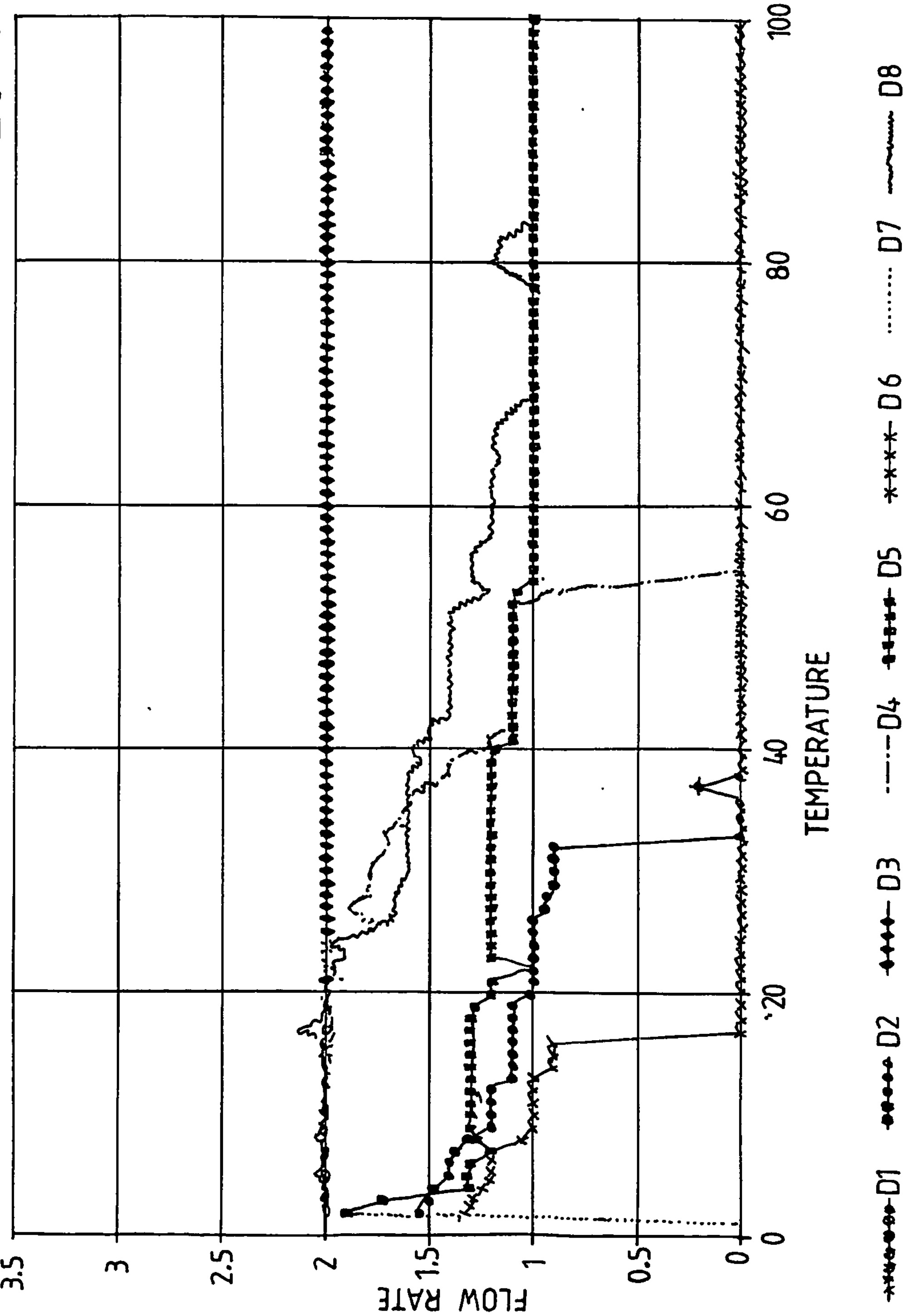


FIG. 5.

FIG. 2.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2.5
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1
0.5
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TEMPERATURE
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20
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60
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D1
D2
D3
D4
D5
D6
D7
D8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU02/01546

A.	CLASSIFICATION OF SUBJECT MATTER
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F24F 13/06, C22B 3/02, 3/18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT: distribut+, hose, pipe+, aerat+, air;
USPTO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4280826 A (Johnson, Jr.) 28 July 1981 See figures 1-6	1-2, 5-8
X	US 4231770 A (Johnson, Jr.) 4 November 1980 See figures 2-5	1-2, 5-8
X	EP 694635 A (PNEUMAFIL CORP) 31 January 1996 See whole document	1-2, 5-8

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:
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Date of the actual completion of the international search	Date of mailing of the international search report
13 December 2002	17 DEC 2002
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer **JOHN DEUIS** Telephone No : (02) 6283 2146

C (Continuation). **DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Derwent Abstract Accession No. 91-170312/23, Class Q74, SU 1596189 A (KIRILENKO N YA) 30 September 1990	1-2, 5-8
X	Derwent Abstract Accession No. 86-250412/38, Class Q74, SE 8600353 A (RC LINJAKY) 29 July 1986	1-2, 5-8

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU02/01546

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	4280826	AR	220869	AU	62488/80	BR	8005958
		CA	1151081	DK	3939/80	EP	26087
		ES	495526	ES	8106090	FI	802900
		HK	947/87	IL	60940	IN	152765
		JP	56053719	KR	8301385	NO	802755
		NZ	194746	SG	647/87	SU	1037829
		US	4231770	ZA	8005355	US	4289511
		US	4297115				
EP	694635	BR	9502370	CA	2154735	US	5505385
SU	1596189	NONE					
SE	8600353	DK	247/86	FI	850360	NO	860296

END OF ANNEX